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Gunn effect and possibility for FIR radiation in strained 2D InGaAs/AlGaAs structure

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Powerful IR emission of hot holes in a strained 2D InGaAs/AlGaAs structure has been observed in [1]. The emission have clear pronounced threshold with respect to excitation (electric field) against the saturation of the current–voltage characteristic of the structure. It is supposed there that powerful emission can be a manifestation of generation and the saturation is due to a domain of high electric field arising. Both effects are to be suppose due to redistribution of hot holes between quantum subbands under a strong electric field. For check this supposition the more detail transport and FIR emission investigations of the structure have been carried out.

Preparation of the samples under investigations are the same that was used in [1]. A pulse electric field of 1 mcs duration was applied to the samples. Shape of voltage and current was controlled by oscilloscope. Values of voltage and current was measured by means of synchronous detector gate of which can be shifted relatively to the beginning of the pulse. In electric field about 1 kV/cm a downfall of current appears at time of 0.5 μs after beginning of the pulse. With increasing of an electric field the downfall of current becomes bigger but its position in time remains the same. In electric field about 3 kV/cm a new downfall of current appears at time of 1 μs after beginning of the pulse and slowly shifts to the beginning of the pulse with increasing of an electric field (see Fig. 1).

At this situation a view of current–voltage characteristic dependents from time position of synchronous detector gate. Fig. 2 shows the current–voltage characteristics at different gate positions respectively to the beginning of the pulse. One can clear see that at gate position before the first current downfall the current goes to the saturation monotonously. At gate position in time of the first downfall the current–voltage characteristic has a negative part so as at gate position in time of the second current downfall one oscillates with increasing of an electric field which indicates a change of domain velocity.

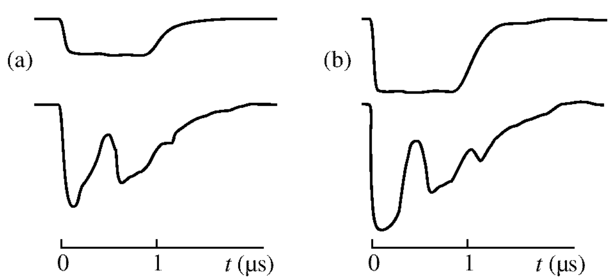

Fig. 1. Shape of voltage (upper curves) and current (lower curves) for electric field of 5 kV/cm (a) and 10 kV/cm (b).

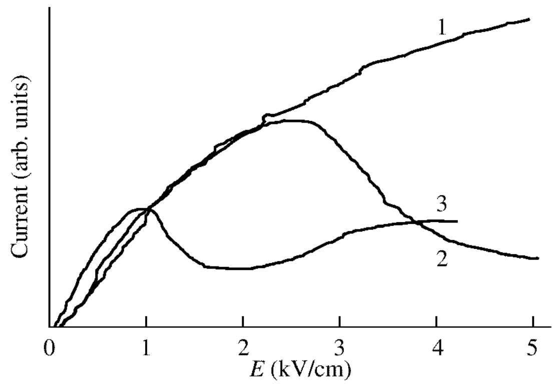

Fig. 2. Current–voltage characteristics at different gate position. Gate position with respect to the beginning of the pulse, μs: 1—0.2; 2—0.5; 3—1.0.

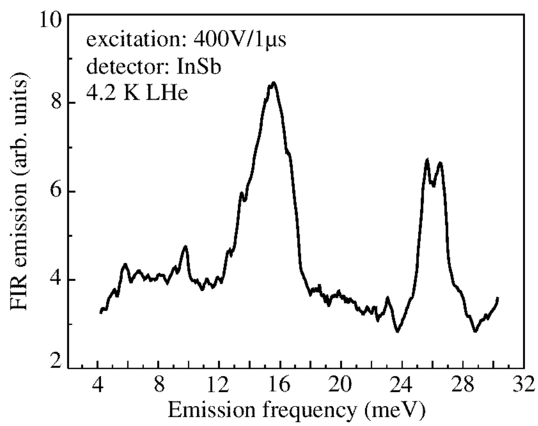

Fig. 3. Spectrum of FIR emission for one of the samples which have superlinear dependence of FIR emission from an electric field (see Fig. 4)

The current oscillations are direct evidence the domain instability existing which can be take place only when the hole effective mass of upper subbands is bigger than one of ground subband like in volume GaAs where the Gunn effect take place. At this situation an accumulation of the holes in upper subbands can occur up to population inversion of hot holes arising. Calculation of hole dispersion curves shows practically isotropic holes at low energy but not parabolic. They effective masses at zero momentum space becomes larger with subband number increasing. The effective mass ratio for first three subbands is 1:1.7:4.4. This is in agreement with experimental data.

In [1] IR emission was observed in wide spectral region of Ge(Ga) photodetector (up to 120 microns including sensitivity of Ge in own region). Now a spectral measurements of the FIR emission have been carried out by means of selective smoothly tuned by a magnetic field InSb detector. The result is shown on Fig. 3. One can see two spectral lines at 16 and 26 meV. The first at 16 meV is sufficiently broad so as second at 26 meV is in three times narrower. Moreover, the second line shape is almost the same for InSb photodetector

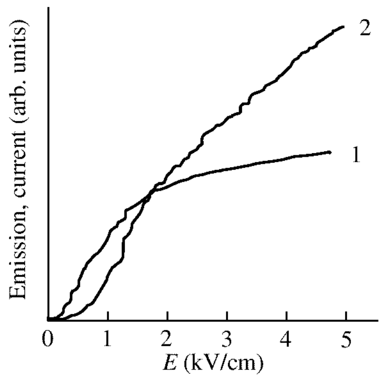

Fig. 4. Dependencies of current (1) and emission (2) vs an electric field.

sensitivity shape obtained independently by means of Fourier spectrometr (spectral width is 1.6 mev) with typical splitting in a magnetic field. It means that this line is a result of InSb photodetectors scanning by a narrow line of emission not more than 0.4 meV. This narrow emission line can be only in the three cases: (i) emission is connected with radiative transition between subbands of cold up to 4.2 K holes, (ii) emission is connected with radiative impurity intracentre transition and (iii) emission is a manifestation of generation. The first possibility can not be realize because a high electric field heats holes at least to 70 K. It one can clear see from the first emission line which has spectral width of 6 meV. The second possibility also can not be realize because impurity concentration in QW is residual and does not exceeds $1.5 \times 10^9\,\mathrm{cm}^{-2}$ which is provided by RIBER machine. It is very small value in comparison with concentration of free holes (about $6 \times 10^{11}\,\mathrm{cm}^{-2}$). The third possibility seems real.

The most samples of the structure have superlinear dependencies of FIR emission measured in a broad spectral region as it is shown in Fig. 4 so as the current tends to saturation. Superlinear character of FIR emission can be explain by accumulation of holes in upper subbands which can lead to population inversion.

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References

[1] Yu. L. Ivánov, C. A. Morosov, V. M. Ustinov and A. E. Zhukov, *Fiz. Tekhn. Poluprovod.* **32**, (9) 1119–1121 (1998).